Aging of the Universe and the fine structure constant

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Abstract

In this paper the aging of the Universe is investigated in the frame of quantum hyperbolic heat transport equation. For the open universe, when $t \to \infty$, $\hbar \to \infty$, $c \to 0$ and fine structure constant, α, is constant.

Key words: Quantum heat transport; Open universe; Fine structure constant.

1 Introduction

The distant future of the Universe is dramatically different depending on whether it expands forever, or it stops expanding at some future time and recolapses. The long term future of life and civilization has been discussed by J. N. Islam [1] and F. Dyson [2]. In this paper we will study the aging of the open universe in which $t \to \infty$. Starting from the quantum hyperbolic heat transfer equation we argue that the Planck time $\tau_P = \left(\frac{\hbar G}{c^5} \right)^{1/2}$ is the border between the time reversible universe $t < \tau_P$ and universe with time arrow for $t > \tau_P$. For time $t \to \infty$ the prevaling thermal process for thermal phenomena in the universe is the diffusion with diffusion constant $D_P = \left(\frac{\hbar G}{c} \right)^{1/2}$, i.e. for $t \to \infty$, $D_P \to \infty$. From formula for D_P we conclude that for $t \to \infty$, $\hbar \to \infty$ and $c \to 0$. In that case from formula for fine structure constant α we obtain $\alpha = $ constant for $t \to \infty$. This result does not exclude the observed very small change of α for redshift $0.5 < z < 3.5$ [5, 6]. The theory with variable c was considered by J. Magueijo [8]. It seems quite interesting that in our scenario, $t \to \infty$, $c \to 0$, $\hbar \to \infty$ the aging universe will be more and more quantum Universe.

2 The time arrow in a Planck gas

The enigma of Planck era i.e., the event characterized by the Planck time, Planck radius and Planck mass, is very attractive for speculations. In this paper, we discuss the new interpretation of Planck time. We define Planck gas – a gas of massive particles all with masses equal the Planck mass $M_P = \left(\frac{\hbar c}{G} \right)^{1/2}$ and relaxation time for transport process equals the Planck time $\tau_P = \left(\frac{\hbar G}{c^5} \right)^{1/2}$. To the description of a thermal transport process in a Planck gas, we apply the quantum Heaviside heat transport equation (QHH) [3]

$$\frac{\lambda_B}{v_h} \frac{\partial^2 T}{\partial t^2} + \frac{\lambda_B}{\lambda} \frac{\partial T}{\partial t} = \frac{\hbar}{M_P} \nabla^2 T. \tag{1}$$

In Eq. (1) M_P is the Planck mass, λ_B the de Broglie wavelength and λ mean free path for Planck mass. The Eq. (1) describes the dissipation of the thermal energy induced by a temperature gradient ∇T. Recently, the dissipation of the thermal energy in the cosmological context (e.g. viscosity) was described in the frame of EIT (Extended Irreversible Thermodynamics) [2].

With the simple choice for viscous pressure, it is shown that dissipative signals propagate with the light velocity c. Considering that the relaxation time τ is defined as [3]

$$\tau = \frac{\hbar}{M_P v_h^2},\tag{2}$$

for thermal wave velocity $v_h = c$ one obtains

$$\tau = \frac{\hbar}{M_P c^2} = \left(\frac{\hbar G}{c^5}\right)^{\frac{1}{2}} = \tau_P,\tag{3}$$

i.e. *the relaxation time is equal to the Planck time* τ_P. The gas of massive particles with masses equal to the Planck mass M_P, and relaxation time τ_P we will define as the Planck gas.

According to the results of paper [3] we define the quantum of the thermal energy, *heaton* for the Planck gas as

$$E_h = \hbar \omega_P = \frac{\hbar}{\tau_P} = \left(\frac{\hbar c}{G}\right)^{\frac{1}{2}} c^2 = M_P c^2,\tag{4}$$

i.e.

$$E_h = \hbar \omega_P = 10^{19}\text{GeV}.\tag{5}$$

With formula (2) and $v_h = c$ we calculate the mean free path λ, viz

$$\lambda = v_h \tau_P = c\tau_P = \left(\frac{\hbar G}{c^3}\right)^{\frac{1}{2}}.\tag{6}$$

From formula (6) we conclude that mean free path for a Planck gas is equal to the Planck radius. For a Planck mass, we can calculate the de Broglie wavelength

$$\lambda_B = \frac{\hbar}{M_P v_h} = \left(\frac{G\hbar}{c^3}\right)^{\frac{1}{2}} = \lambda.\tag{7}$$

As it is defined in paper [3] Eq. (7) describes the quantum limit of heat transport. When formulae (6) and (7) are substituted in Eq. (1) we obtain

$$\tau_P \frac{\partial^2 T}{\partial t^2} + \frac{\partial T}{\partial t} = \frac{\hbar}{M_P}\nabla^2 T.\tag{8}$$

3

Equation (8) is the quantum hyperbolic heat transport equation for a Planck gas. It can be written as

$$\frac{\partial^2 T}{\partial t^2} + \left(\frac{c^5}{\hbar G}\right)^{\frac{1}{2}} \frac{\partial T}{\partial t} = c^2 \nabla^2 T \tag{9}$$

The quantum hyperbolic heat equation (9) as a hyperbolic equation sheds light on the time arrow in a Planck gas. When QHT is written in the equivalent form

$$\tau_P \frac{\partial^2 T}{\partial t^2} + \frac{\partial T}{\partial t} = D_P \nabla^2 T, \tag{10}$$

where $D_P = \left(\frac{\hbar G}{c}\right)^{\frac{1}{2}}$ is the diffusion coefficient for a Planck gas, then for time period shorter then τ_P we have preserved time reversal for thermal processes, viz.

$$\frac{1}{c^2} \frac{\partial^2 T}{\partial t^2} = \nabla^2 T. \tag{11}$$

For the aging of the universe i.e for $t \to \infty$, $t \gg \tau_P$ the time reversal symmetry is broken

$$\frac{\partial T}{\partial t} = \left(\frac{\hbar G}{c}\right)^{\frac{1}{2}} \nabla^2 T. \tag{12}$$

These new properties of Eq. (9) open up new possibilities for the interpretation of the Planck time. Before τ_P, thermal processes in Planck gas are symmetrical in time. After τ_P, i.e. for $t \to \infty$ the time symmetry is broken. Moreover gravitation is activated after τ_P and this fact creates an arrow of time (12).

It is well known that the equation (11) is invariant under Lorentz group transformation whereas equation (12) is not. The time border between two processes domination waves and diffusion is the τ_P. On the other hand τ_P as the time period is dependent on the observer velocity, i.e. can in principle be different for different observers. The wayout which solves the contradictory is to assume that τ_P is invariant under Lorentz transformation. Considering that Planck length is equal

$$L_P = c\tau_P, \tag{13}$$

we obtain that L_P, Planck length is invariant under Lorentz transformation. This conclusion is in harmony with the results of G. Amelino-Camelia paper [4].

3 Inconstancy of the fine structure constant, α?

The contemporary observational method can compare the value of fine structure constant $\alpha = \frac{1}{137}$ in different ages of the universe [5, 6]. For the sources lying between redshifts 0.5 and 3.5 as a whole, the observed shifts is

$$\frac{\Delta\alpha}{\alpha} = \frac{[\alpha(z) - \alpha(\text{now})]}{\alpha(\text{now})} = (-0.72 \pm 0.18)10^{-5}. \tag{14}$$

If one converts this into a rate of charge of α with time it amounts to about

$$\frac{(\text{rate of change of } \alpha)}{(\text{current value of } \alpha)} = 5 \cdot 10^{-16} \text{per year} \tag{15}$$

One of the author of the papers [5, 6] once write on the constant of nature [7]:

> There is something attractive about permanance. We feel instinctively that things that have remained unchanged for centuries must posses some attribute that is instrinsically good. . . . And despite the constant flux of changing events, we feel that the world possesses some invariant bedrock where general aspect the same.

I still share this point of view and assume α is constant through the evolution of universe. But the aging of the Universe means the transition from wavy motion to the diffusion i.e the diffusion is dominant for $t \to \infty$. The growing influence of diffusion term in equation (2) means:

$$D_P = \left(\frac{\hbar G}{c}\right)^{\frac{1}{2}} \to \infty, \qquad \text{for} \qquad t \to \infty$$

i.e. (when $G = $ constant) $\hbar \to \infty$, $c \to 0$ for $t \to \infty$. In this scenario $\alpha = \frac{e^2}{\hbar c}$ can be constant through the life of the universe – our Universe.

One of the conclusion that for $t \to \infty$, $c \to 0$ is in harmony with new results of João Magueijo [8] on the varying of the light sped. It is interesting to observe that in our scenario, i.e. $c \to 0$, $\hbar \to \infty$ for $t \to \infty$ the aging Universe will be more and more quantum Universe with prevaling quantum effects over the classical behaviour. Who knows?

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